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Departmental Report

PRELIMINARY RESULTS OF DD-963 MODEL TESTS IN BROKEN ICE FIELDS

by

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DTRC/SHD-1315-01 Preliminary Results of DD-963 Model Tests in Broken Ice Fields

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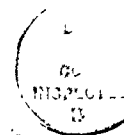
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ABSTRACT

This report presents the preliminary results of tow basin tests conducted with a model of the DD963 in fields of simulated broken ice cover representing conditions found in the Marginal Ice Zone (MIZ). Model tests were also performed in conditions representing broken ice in a confined ice channel which has been prepared for passage by an icebreaker. The test program was directed toward the definition of speed limits as a function of ice concentration for non-interference of ice floes with the sonar dome, bilge keels, propellers, and rudders. Recommendations for future model tests are discussed.

ADMINISTRATIVE INFORMATION

This investigation was sponsored by the Naval Sea Systems Command, Office of Research and Development, SEA 05R2 under the Ice Tolerant Hull Structures and Appendages Task 28679, Program Element 63514, of the Ship Survivability Program. It is identified as Work Unit Number 1-1202-913 at the David Taylor Research Center (DTRC).

INTRODUCTION

The Maritime Strategy for the U. S. Navy includes a requirement to project seapower into northern latitude regions. To achieve this goal, Navy surface forces must overcome three major environmental threats in order to operate effectively in cold weather regions. These threats are topside icing, heavy seas, and floating ice. Floating ice represents a unique obstacle to surface ship operations because it serves as a barrier in an otherwise open ocean area and because it has the potential to inflict damage on the hull and appendages of Navy ships¹.

It is generally accepted in the Navy today that surface ships should not attempt to penetrate solid ice packs because of insufficient hull and appendage strength. In fact, the typical warship has a hull and appendages which are unsuitable for pack ice penetration. Some specific potential problem areas are shown and listed in Figure 1.

The Marginal Ice Zone (MIZ) is a region of broken sea ice that exists between the ice pack and open water. Questions have been raised as to whether or not surface ships

can penetrate and safely operate in the MIZ². At the present time, the Navy has no detailed definition of its surface ship capabilities in this region. One means of estimating the Navy's capabilities might be to send a group of ships into the MIZ and learn our lessons from direct experience. This, as an initial step, is not a good idea due to constant changes in ice concentration and ice pressure in the MIZ which might cause significant damage to our "thin-skinned" ships. A better and more cost effective approach would be to estimate whether or not surface ships could safely approach regions of floating ice in the first place by using existing model testing techniques. This approach has recently been demonstrated by Code 1561 of the David Taylor Research Center (DTRC).

PURPOSE

Basic questions exist regarding a ship's approach to the MIZ. For instance, are hull appendages vulnerable to ice impacts? Is the sharp stem on typical Navy combatants particularly vulnerable to ice impacts? Are there different limiting speeds at which a ship can operate in different concentrations of broken ice? Can Navy ships make a safe transit through a broken ice channel left by an icebreaker? The purpose of this model test program was to provide a first order answer to these basic questions by observing the interaction of simulated broken ice with a modern Navy hullform.

MODEL SELECTION

A search was initiated to select a modern hull form which represented a typical Navy combatant. It was quickly realized that the SPRUANCE Class destroyer and the TICONDEROGA Class cruiser represent a significant portion of the modern day warship fleets. Both the DD963 and the CG47 also have the same hull below the waterline with the exception of the draft. If conservative model testing techniques were employed, information obtained through the testing of one hull configuration would provide conservative guidance for two classes of warships. Therefore, this hullform was chosen for the model test. The draft of the CG47 is approximately 2 feet (.6 meters) deeper than that of the DD963. In terms of ice interaction with the hull and appendages, the model configuration having the shallower draft was chosen to represent the more severe case. As a result, a model test was conducted using the DD963 configuration.

An existing model built to a scale factor of 24.8 was used in the test program. This model is shown in Figure 2.

SELECTION OF MODEL ICE MATERIAL

Since Navy ships are not ice strengthened, it can be conservatively assumed that ice impacts with the hull and appendages may cause damage. With recent emphasis placed on the acoustic silencing of surface ships for antisubmarine warfare, even minor damage to propellers cannot be tolerated. Rips and tears in the sonar dome rubber window will provide sources of flow noise and degrade sonar system performance. Bilge keels are carefully aligned with the flow over the hull to maximize effectiveness and minimize resistance³. Ice damage to bilge keels can reduce overall seakeeping performance, increase drag, and produce unnecessary flow noise. Therefore, it can safely be assumed that the occurrence of an ice impact at any of the above locations is unacceptable. This assumption simplifies the selection of model ice material because it eliminates the necessity to scale the strength properties of the ice. The use of real ice or urea ice is not required because there is no longer a need to model the crushing properties of the ice. Other materials can be used to model the ice at a considerable savings in test costs.

Critical properties for the model ice in this experiment were then determined to be proper geometric scaling, in terms of size and thickness, and the proper specific gravity of 0.9. It was also desirable to select a material which was hard and rigid in order to permit use of the material in subsequent tests. Polypropylene was the material of choice for the smaller ice floes. Ballasted foam was used to model the larger ice floes with the objective of minimizing damage to the ship model due to impacts with the larger floes⁴.

TEST CONDITIONS

Model tests were conducted in simulated open ice fields which were representative of those quantified during the 1986 Polar class Bering Sea ice edge deployment^{4,5}. Both forward speed and backing tests were conducted in simulated ice fields ranging in ice concentration from 20 to 100 percent, at full scale speeds ranging from 2 to 20 knots. A typical model ice field is displayed in Figure 3. Similar tests were also conducted in

confined channels of varying channel widths with both self-propelled and towed models. The primary data collection effort consisted of recording the behavior of the ice pieces as the ship model moved through the ice fields with five video cameras and recorders. Two above water and two underwater cameras were fixed on the tow carriage and focused on the bow and stern portions of the model. This camera configuration allowed the cameras to move with the model and thus eliminate of motion-dependent interactions. One stationary video camera recorded the underwater passage of the model through a window in the side of the tow tank.

RESULTS

Portions of the DD963 model were found to be particularly vulnerable to ice impacts. These parts included the stem, sonar dome, bilge keels, propeller shaft brackets, propellers, and rudders. In general, for ahead operation at low speed in ice fields of low concentration, the ice floes were well behaved, maintaining their horizontal orientation on the surface of the water, and simply being pushed aside as the ship passed through the ice field. At forward speeds between 5 and 7.5 knots, ice impacts became significant at the stem. Analysis of video footage indicated that as the ship speed or ice concentration increased, the horizontal displacement of the ice floes became constrained or restricted. Some of the ice floes in contact with the ship were forced from a horizontal to a vertical orientation. A further increase in forward speed caused some of the vertically oriented floes to be driven downward as they touched the hull, impacting with the sonar dome. A typical sonar dome impact is displayed in Figure 4. As ice concentrations increased, ice floes would then impact the bilge keels, the propeller shaft brackets, and finally the propellers and rudders. While the quantitative analysis of the data had not been completed at the time this report was prepared, preliminary indications are that ice floe impacts with the sonar dome can be expected at a forward speed of approximately 7.5 knots. Further, preliminary indications are that this speed limit for ice floe interaction will decrease somewhat as the ice concentration increases from 20% to 100%.

Variations in ice concentration also appear to influence ice interaction with the propellers and rudders. At the higher concentrations ice floes tended to be pushed

under the turn of the bilge along a path to the propellers by the surrounding, compacted ice field. For example, at a broken ice concentration of 100%, ice interaction with the propellers was observed at a forward speed of only 6.5 knots.

The situation for astern operation of the ship in the MIZ conditions was observed to be even more severe. Instead of gently pushing ice floes to one side of the hull, as was observed at the bow during slow speed tests in the forward direction, the flat portion of the transom stern provided a resting place for ice floes as the ship moved astern. As backing speed increased, a threshold was reached where the ice floes folded themselves under the transom. At a speed of only 2 to 3 knots astern, at all ice field concentrations tested, the ice pieces would flip under the transom stern, strike the rudders and move directly into the propellers. The expected result would be substantial damage to the propellers.

In general, the tests performed in the confined ice channel simulating a path prepared in continuous level ice cover by an escorting icebreaker revealed even more severe ice interaction with the ship. For example, ice interaction with the propellers due to ice entering the propeller region from the sides of the hull was observed for the confined channel case at a forward speed of only 5 knots. In addition, under confined channel conditions at higher speeds on the order of 10 knots, ice was observed to be driven down along the hull at the bow, pass under the entire length of the vessel, and finally move directly into the propellers. The downward displacement of model ice floes in a typical confined channel test is displayed in Figure 5. In the MIZ open water tests, the ice driven down by the bow generally resurfaced well before the stern passed.

CONCLUSION

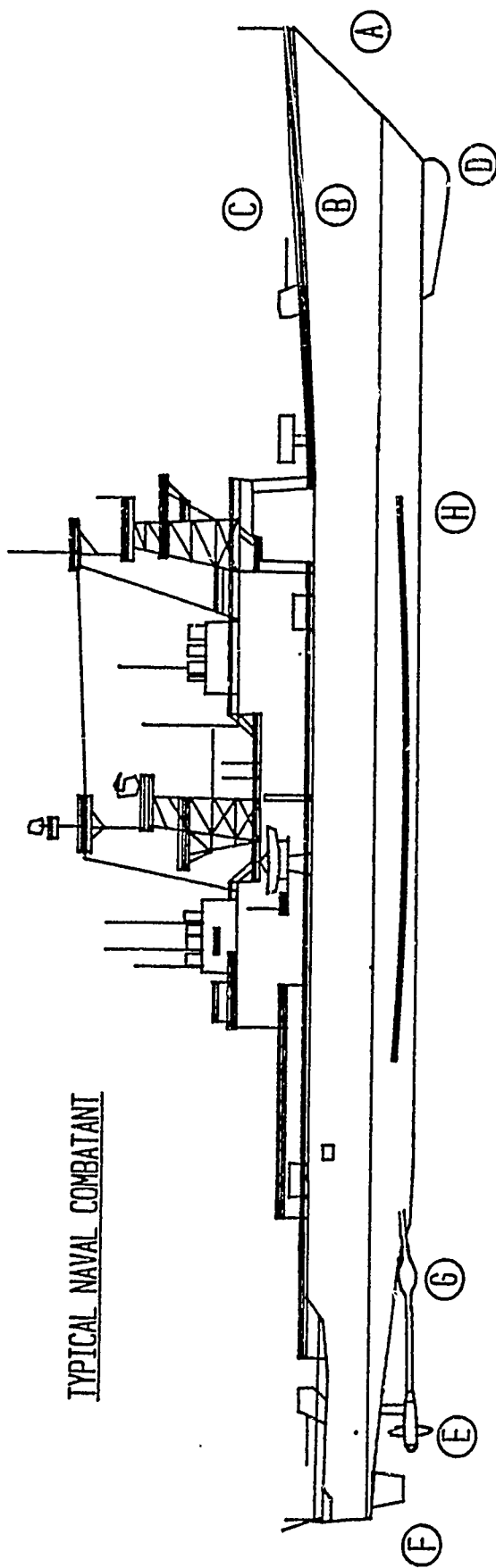
Based on a preliminary review of the data gathered from this model test, it is estimated that the DD963 has limited transit capability at significantly reduced speeds in the Marginal Ice Zone. This capability primarily varies with ship speed, and is limited by the vulnerability of hull appendages to ice impacts. Forward speed in the MIZ will be limited to approximately 5 and 7.5 knots in open water due to ice impacts at the stern and sonar dome. It must be emphasized that this model test did not assess the magnitude of ice impact loads to the hull and appendages. This information is

essential to determine whether ice impacts at the stern are more significant than sonar dome ice interaction in terms of defining a limiting speed in the ahead direction. Test efforts by DTRC in 1990 will be directed toward the measurements of these impact loads. Backing must be undertaken with extreme care at a speed of only 2 to 3 knots. Similar conclusions can be made and applied to the CG47 with consideration given to the deeper draft. A deeper draft simply makes the existing conclusions slightly more conservative on the side of ship safety.

The testing method utilized in this experiment appears to have provided both realistic and reasonable results. The observed interaction of the ice and the hull in the simulated ice field was in excellent agreement with field observations made during ice deployments in the Bering Sea and Labrador Sea. Test results are in good agreement with general guidance found in existing navigation publications ^{1,6,7,8,9}.

Further model testing would be a good means of establishing operational limits on other warships which have hull configurations which are significantly different than the DD963. Ice interaction with combatant ships appears to be influenced by the slenderness of the hull, draft, trim, sonar dome location, hull form at the stern, and the propeller and rudder configuration. The FFG7 would make an excellent candidate due to its single screw/single rudder configuration, recessed sonar dome, and bilgekeel/fin stabilizer arrangement.

TYPICAL NAVAL COMBATANT



Potential Structural Inadequacies for Surface Combatants Operating in Ice or Extreme Cold Regions:

- A) Hull not configured for breaking ice.
- B) Hull shell structure not designed for ice loading (no icebelt)
- C) Low temperature steels not utilized.
- D) Sonar dome rubber window structure exposed to ice impact.
- E) Controllable pitch propeller not designed for ice milling.
- F) Balanced rudder subject to ice impact.
- G) Shafts and struts exposed to ice impact.
- H) Bilge keels subject to ice impact.

Fig. 1. Typical Surface Combatant

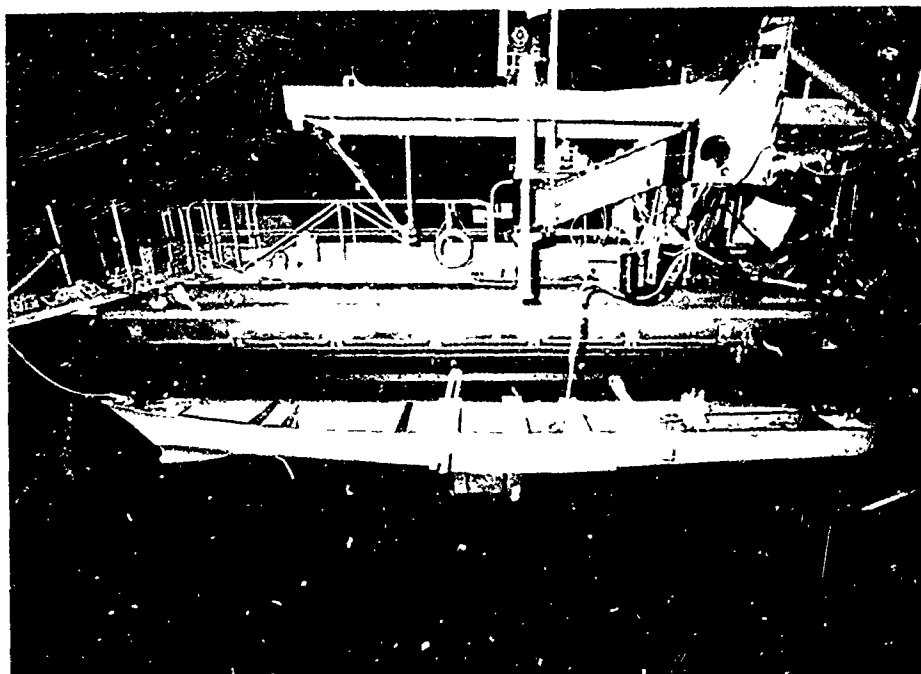


Fig. 2. DD-963 Model Used in Broken Ice Field Test at DTRC.

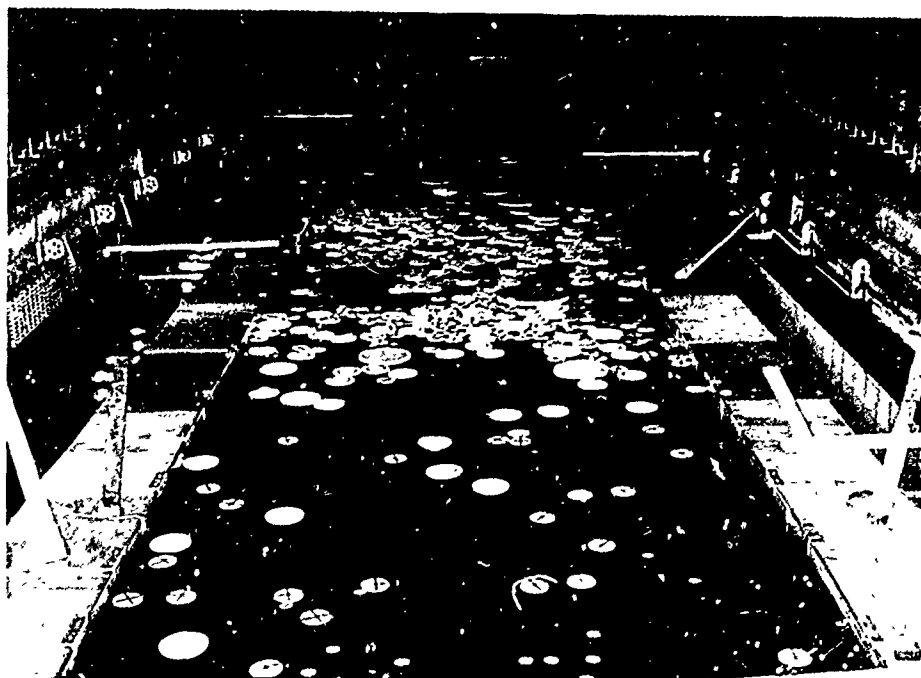


Fig. 3. Typical Simulated Broken Ice Field.

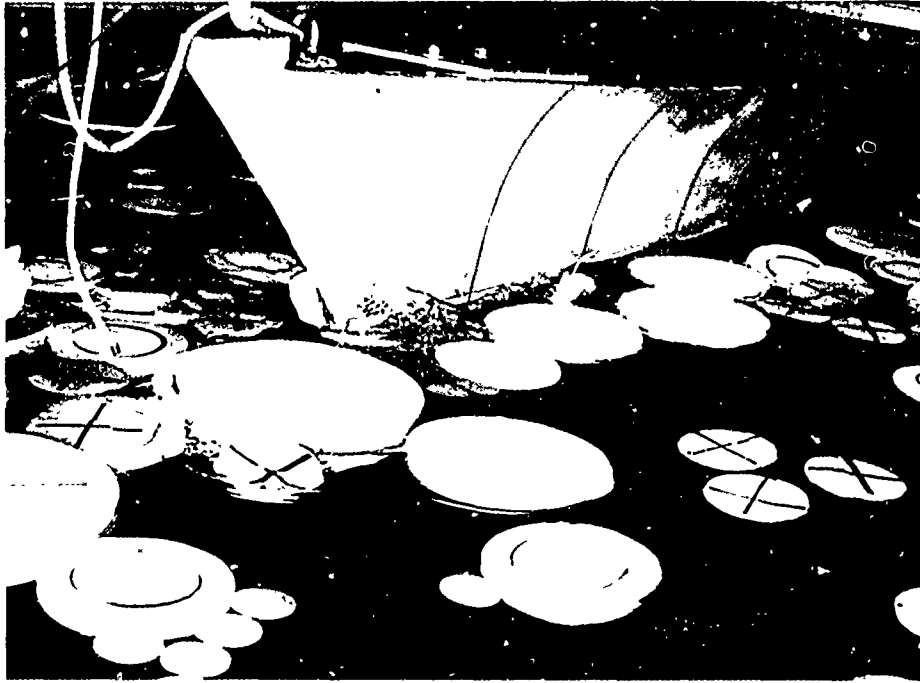


Fig. 4. Typical Sonar Dome Model Ice Impact.



Fig. 5. Typical Interaction for Hull Underside in a Confined Channel.

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